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TECHNICAL NOTE

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EFFECT OF FORWARD VELOCITY ON SOUND-PRESSURE LEVEL IN THE NEAR NOISE FIELD OF A MOVING JET

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EFFECT OF FORWARD VELOCITY ON SOUND-PRESSURE LEVEL IN THE NEAR NOISE FIELD OF A MOVING JET

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SUMMARY

An inflight investigation of the near noise field along the boundary of an aircraft-mounted jet engine was conducted over a flight Mach number range of 0.35 to 0.70 at altitudes of 10,000, 20,000, and 30,000 feet, at 2 and 3 nozzle-exit diameters downstream of the jet exit.

The sound-pressure levels were found to be constant over the full Mach number range.

The results of the experiment tend to substantiate predictions of the Mach number effect on jet noise production.

INTRODUCTION

The high noise levels of turbojet engines have created a demand for experimental clarification of the influence of forward motion on jet noise production. Experiments have been conducted on jet aircraft flying over stationary ground observation points (e.g., ref. 1); this represents the far-field case of a moving source (in the sense of motion of the aircraft) and a fixed observer. The present tests represent the near-field case of a moving source and a moving observer in a stationary medium. Both types of measurement are of interest.

One means of studying the effect of forward motion on jet noise production is to make measurements of the near noise field of the jet both statically and in flight. These measurements are possible through the use of streamlined microphone shields of very low self noise.

Predictions of the changes in near-field sound-pressure levels resulting from changes in forward velocity of typical jet engines are possible if a few assumptions concerning the mechanism of jet noise production are made. These assumptions and the resulting calculations are based on engine parameters and on near-noise-field measurements of stationary jet engines (ref. 2).

The purpose of the investigation reported herein was to measure experimentally the effect of forward velocity on the near noise field of a moving jet.

These tests were conducted over a range of Mach number from 0.35 to 0.70 at altitudes of 10,000, 20,000, and 30,000 feet using a single-engine fighter-type jet aircraft.

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APPARATUS

The aircraft used in this investigation was powered by a single J-33 turbojet engine. This aircraft provided room for an engineer observer as well as for the pilot, and for the installation of the measuring equipment.

The microphone was mounted on a rigid boom attached to the aft section of the aircraft in such a way that the position of the microphone could be adjusted to lie just outside the boundary of the jet stream in the near noise field (see figs. 1 and 2). The microphone was a small condenser type with an included preamplifier. The microphone assembly was rubber-mounted in an enclosure formed as a body of revolution of a high-speed airfoil section; it was fitted with a wind screen that was made from fine-mesh stainless-steel screen rolled to reduce surface roughness.

The electrical output of the microphone preamplifier was recorded on a flight-type tape recorder mounted in the nose section of the aircraft (fig. 3). The tape recorder provided a sufficient number of channels for the recording of such data as Mach number, altitude, and other pertinent information, as well as a separate channel for microphone data.

The data were reduced on a 1/3-octave-band audiofrequency spectrometer and automatic recorder.

The response of the system from the microphone to the spectrometer tape was within 1 decibel of flat for a frequency range from 50 to 8,000 cycles per second, as shown in figure 4. A block diagram of the system electronics is shown in figure 5.

PROCEDURE

Near-field measurements of noise from the jet were made at 2 and 3 nozzle-exit diameters downstream of the nozzle. Measurements were made over a range of Mach number from 0.35 to 0.70 at pressure altitudes of 10,000, 20,000, and 30,000 feet.

Before and after each test flight a 400-cycle calibration signal was introduced through the system. The source of this signal was a General Radio type 1307-A oscillator and calibrator applied to the boom-mounted microphone. The sound-pressure level of the calibration signal was 121 decibels. (All sound-pressure levels in this report are stated in decibels (db) and are based on a reference level of 2×10^{-4} dynes/cm^2.)

The procedure for taking the inflight data consisted of the following: The aircraft was trimmed to level flight at the test altitude and then slowed to minimum safe airspeed by reducing the engine thrust to idle. At this point the recorder was turned on to obtain a record of the background noise levels. The engine was then set to the 100-percent-rpm level, and the aircraft was allowed to accelerate. The pilot maintained a constant pressure altitude and called out the indicated Mach number in 0.05 steps. When the forward airspeed reached the limitation of the aircraft, the engine thrust level was again reduced to idle in order to allow the background level at the high flight speed to be recorded. The time duration of each test run was about 3 minutes.

The verbal Mach number markers were recorded on a separate channel of the magnetic tape to provide a means of correlating the sound-pressure levels with the aircraft Mach number.

The data were reduced by playing back the recorded sound data through the aforementioned 1/3-octave-band filter assembly and automatic recorder. The Mach number data were marked on the automatic-recorder tape manually by the operator.

The noise data for each flight run were reduced at each 1/3-octave band over the usable range of frequency as well as for the over-all frequency range. This allowed the spectrum of the noise field to be studied for any Mach number effect.

The attenuation due to the wind screen was determined by comparing ground-run data with results taken with the wind-screen removed. This correction is the only one that was applied to the data.

During all test runs, with the engine at the 100-percent-rpm condition, the background level was at least 6 decibels below the data level.

RESULTS AND DISCUSSION

The results of this investigation show that, for the range and scope of this experiment, the sound-pressure levels of the near-field jet noise are independent of aircraft velocity. A study of the curves in figure 6 shows no effect of Mach number on over-all sound-pressure level within the 1.0-decibel readability of the data. Figure 6(c) is a copy of a typical data tape as obtained from the automatic recorder. This result substantiates the predictions of Mach number effect mentioned in the initial summary of this report. The assumptions used in such a prediction are that: (1) The near-field noise production of a jet is a function of the difference between the velocity of the jet and the velocity of the ambient or free-stream air into which the jet is mixing, and (2) this function of velocity is of low order (perhaps first or second power) in the region considered (2 and 3 nozzle-exit diameters downstream of the jet exit). The second assumption is based on the available studies of measurements in the near noise field of stationary jets (e.g., ref. 2). A sample of the resulting calculations is shown in the appendix.

The only observable parameter that seemed to have any effect on the near-field noise levels was that of altitude, as shown in figure 7. This altitude effect is probably due, for the most part, to the decrease of ambient density with increasing altitude. The absolute change of sound-pressure level with altitude is not derived because of the unknown change in microphone sensitivity with changing ambient pressure.

It should be pointed out that the ground-level point in figure 7(b) seems to be high, which may have resulted from impingement of the jet on the microphone.

The engine exhaust pressure ratio during all test runs was always less than 2 and usually less than 1.85.

Examination of the spectral data reported herein (fig. 8) shows that, while the whole spectrum changes in level with altitude, there is very little shift within the spectrum as a function of Mach number. Only the spectra for the 10,000-foot-altitude flight condition are plotted, because they show the largest amount of change.

CONCLUSIONS

Acoustical measurements in the near noise field of a jet aircraft in flight indicated that:

1. The sound-pressure levels of noise produced by the jet were independent of aircraft Mach number within the range of Mach number covered in the investigation (0.35 to 0.70) and within the readability of the data (1 db).

2. The observed value of sound-pressure level decreased with increasing pressure altitude.

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APPENDIX - CALCULATIONS FOR PREDICTION OF NEAR-FIELD JET NOISE

Jet velocity as a function of forward speed can be obtained from jet-engine data.

The engine used in this investigation produced the following values of $V_j - V_0$ at a 10,000-foot pressure altitude:

Condition	M_0	$V_j - V_0$, ft/sec
1	0.40	1316
2	.70	1202

where M_0 is the aircraft Mach number, V_0 is the aircraft velocity, and V_j is the velocity of the jet. Assumption 1 (given in text) implies that

$$\Delta db = -20 \log\left[\frac{(V_j - V_0)_1}{(V_j - V_2)_2}\right]^{\eta}$$

where Δdb is the difference in sound-pressure levels between conditions 1 and 2, and η is a positive number. Assumption 2 requires that

$\eta = 1$ or 2 (for the zone between 2 and 3 diameters as covered in this investigation)

A prediction based on these two assumptions gives the following results:

$$\Delta db = -20 \log\left[\frac{1316}{1202}\right]^{\eta}$$

or

$$\Delta db = -0.79 \qquad \text{for} \quad \eta = 1$$

and

$$\Delta db = -1.58 \qquad \text{for} \quad \eta = 2$$

Both of these small values, especially the value for $\eta = 1$, could have gone undetected in this experimental investigation.

Similar results are obtained at the other altitudes covered in the experiment.

REFERENCES

1. Greatrex, F. B., and Brown, D. M.: Progress in Jet Engine Noise Reduction. Rolls-Royce Ltd. (England).

2. Howes, Walton L., Callaghan, Edmund E., Coles, Willard D., and Mull, Harold R.: Near Noise Field of a Jet-Engine Exhaust. NACA Rep. 1338, 1957. (Supersedes NACA TN's 3763 and 3764.)

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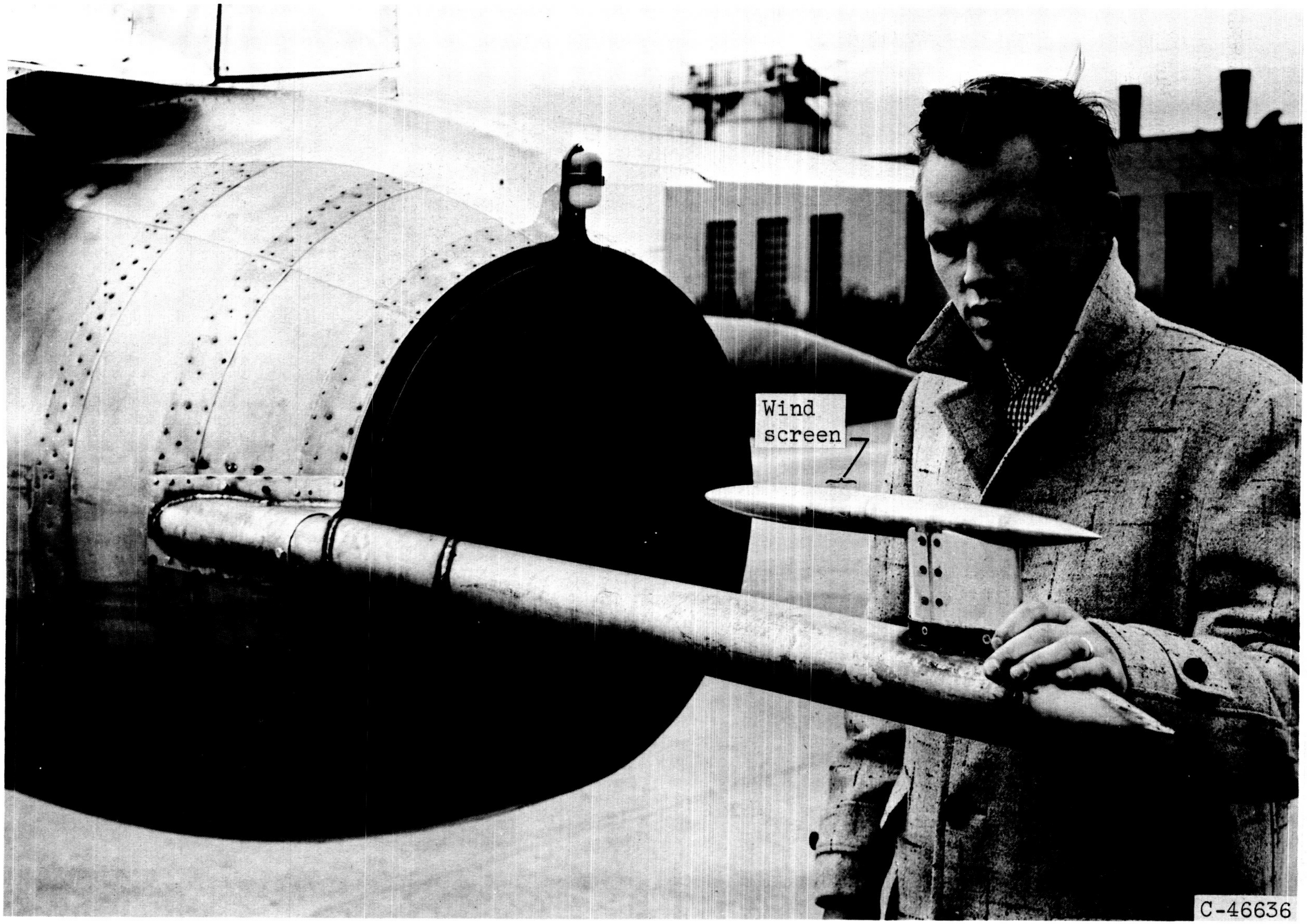


Figure 1. - Tail boom and microphone housing.

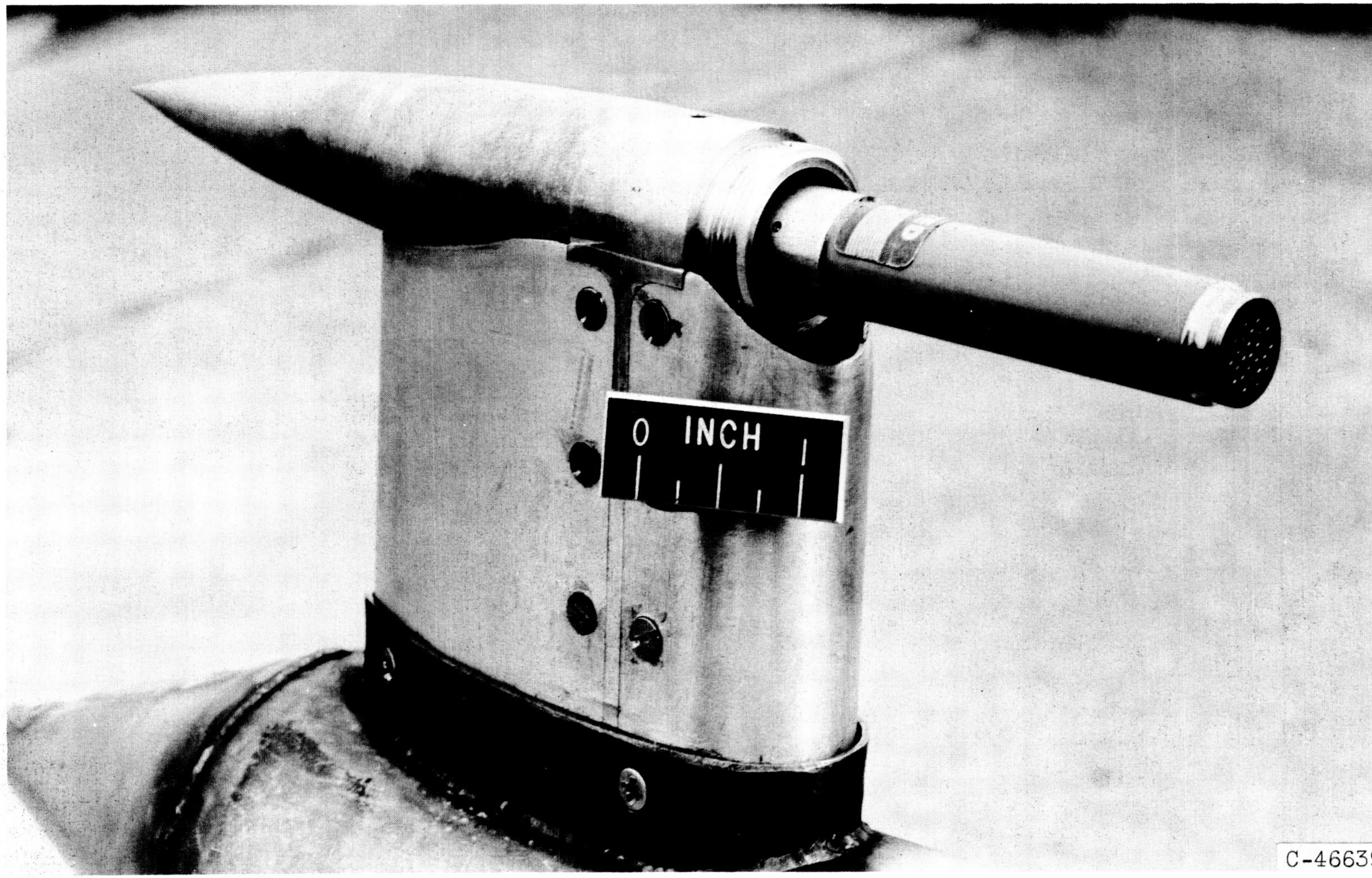


Figure 2. - Microphone housing with foresection removed.

Figure 3. - Tape recorder and electronics.

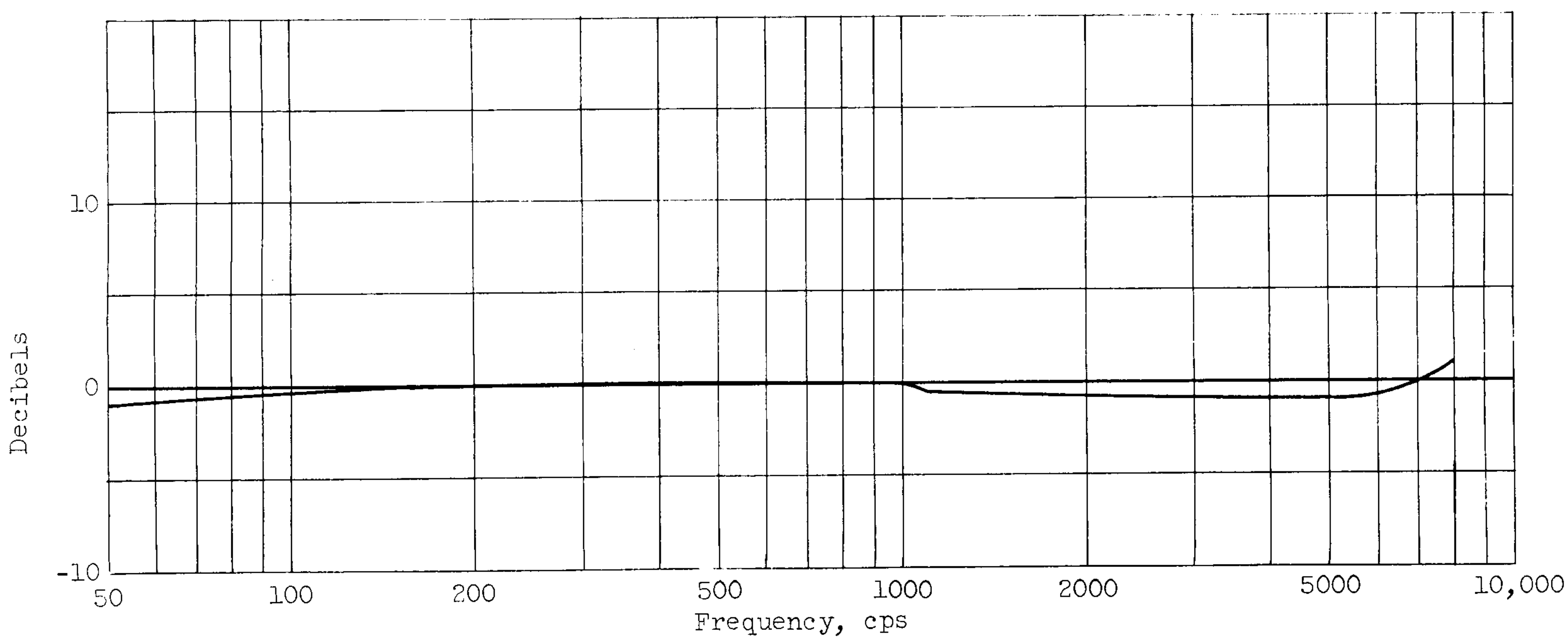


Figure 4. - Frequency response of electrical system including microphone.

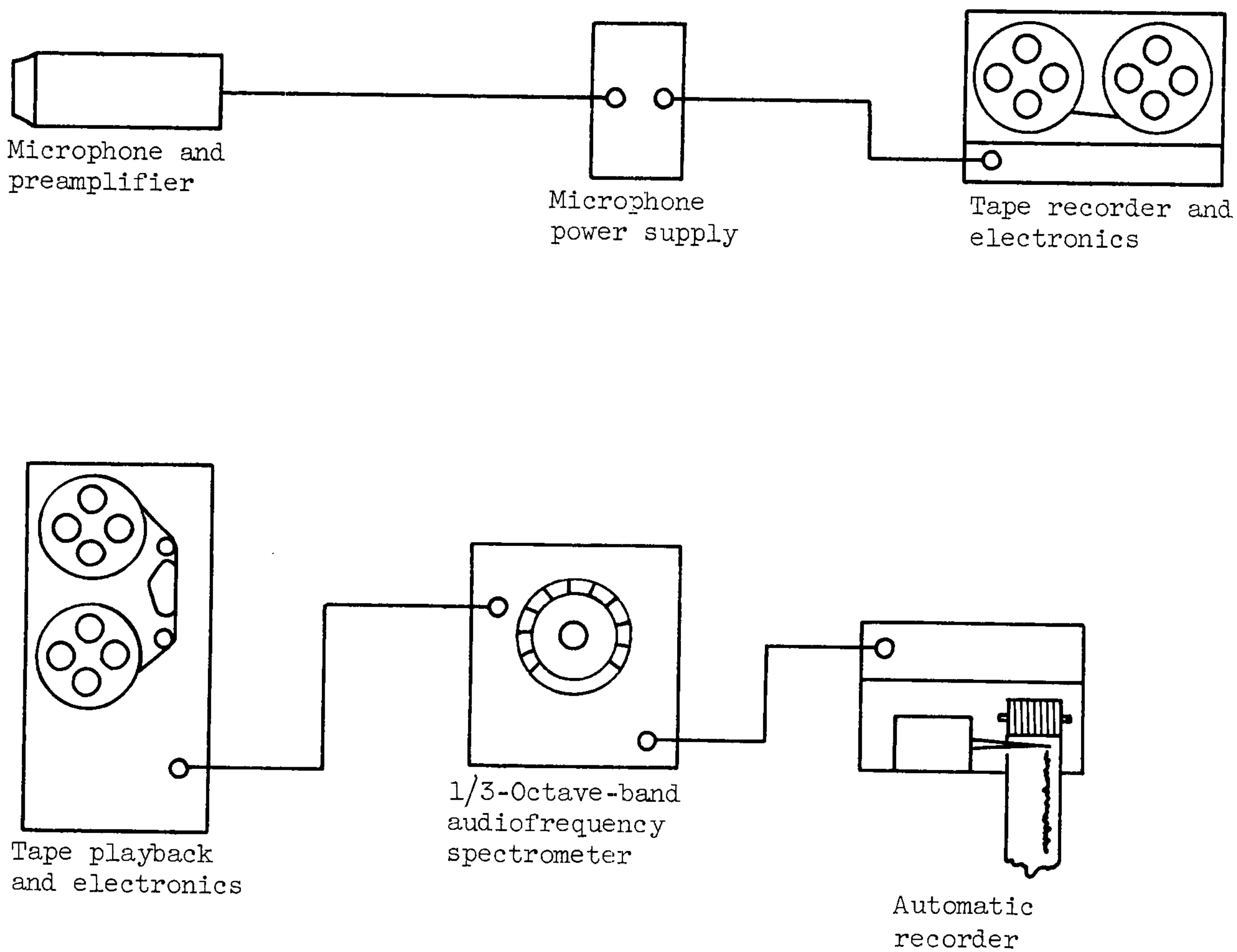
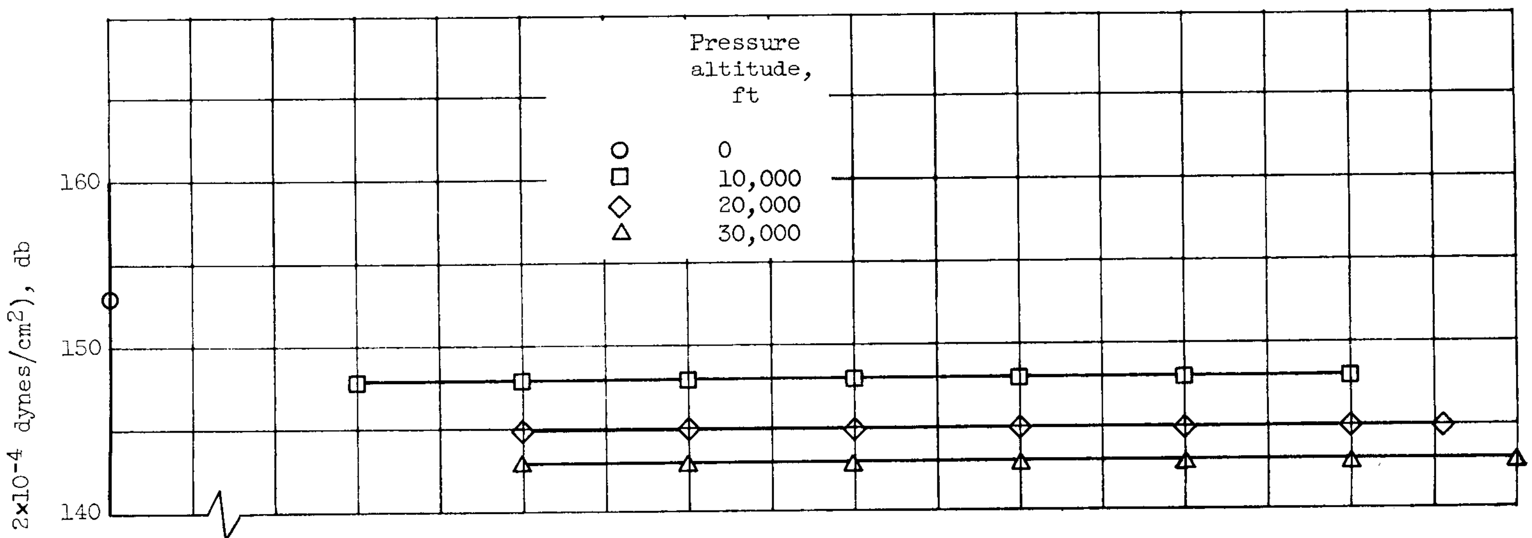
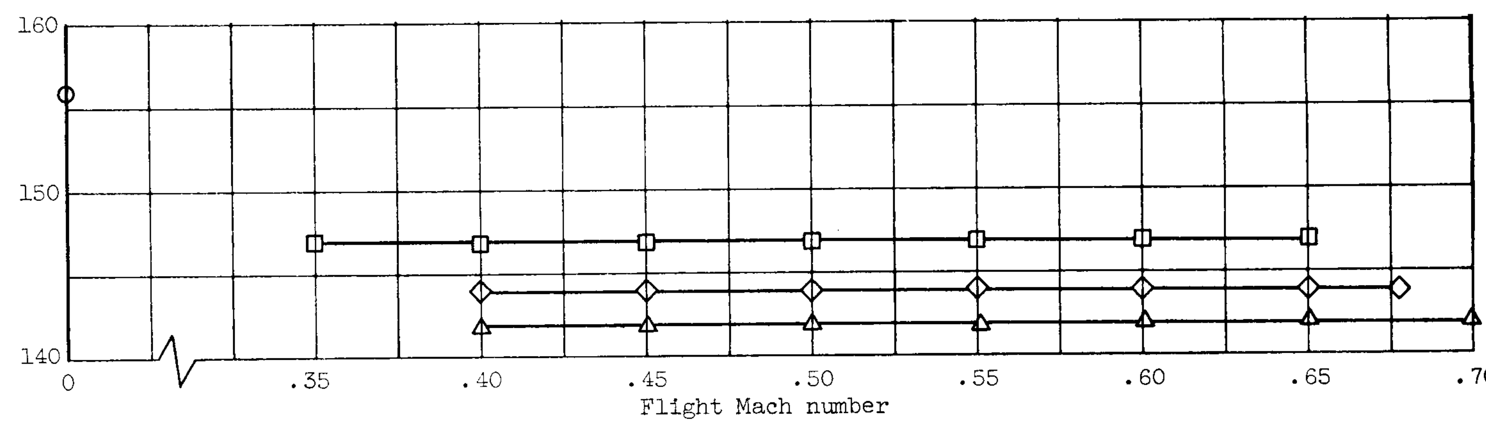


Figure 5. - Block diagram of instrumentation.

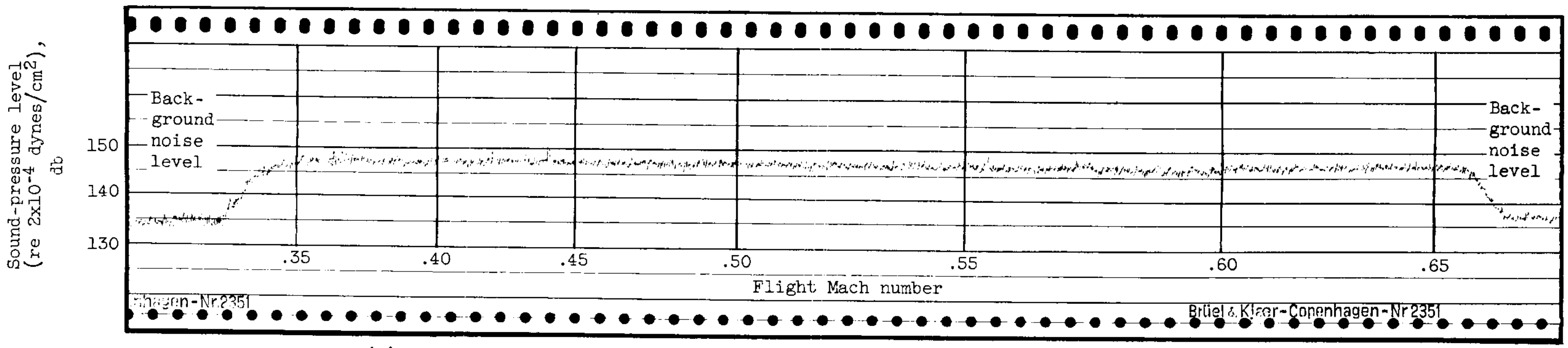


(a) Microphone positioned at 2 nozzle diameters.



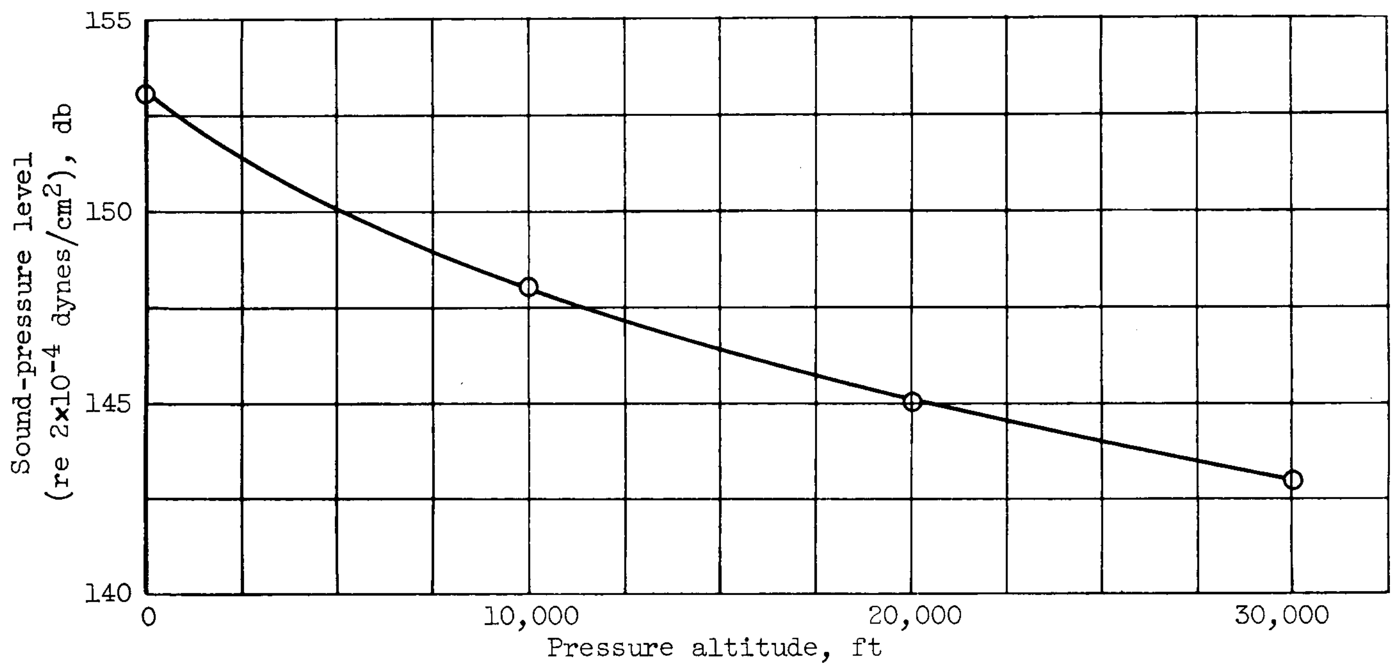
(b) Microphone positioned at 3 nozzle diameters.

Figure 6. - Sound-pressure level as a function of Mach number.



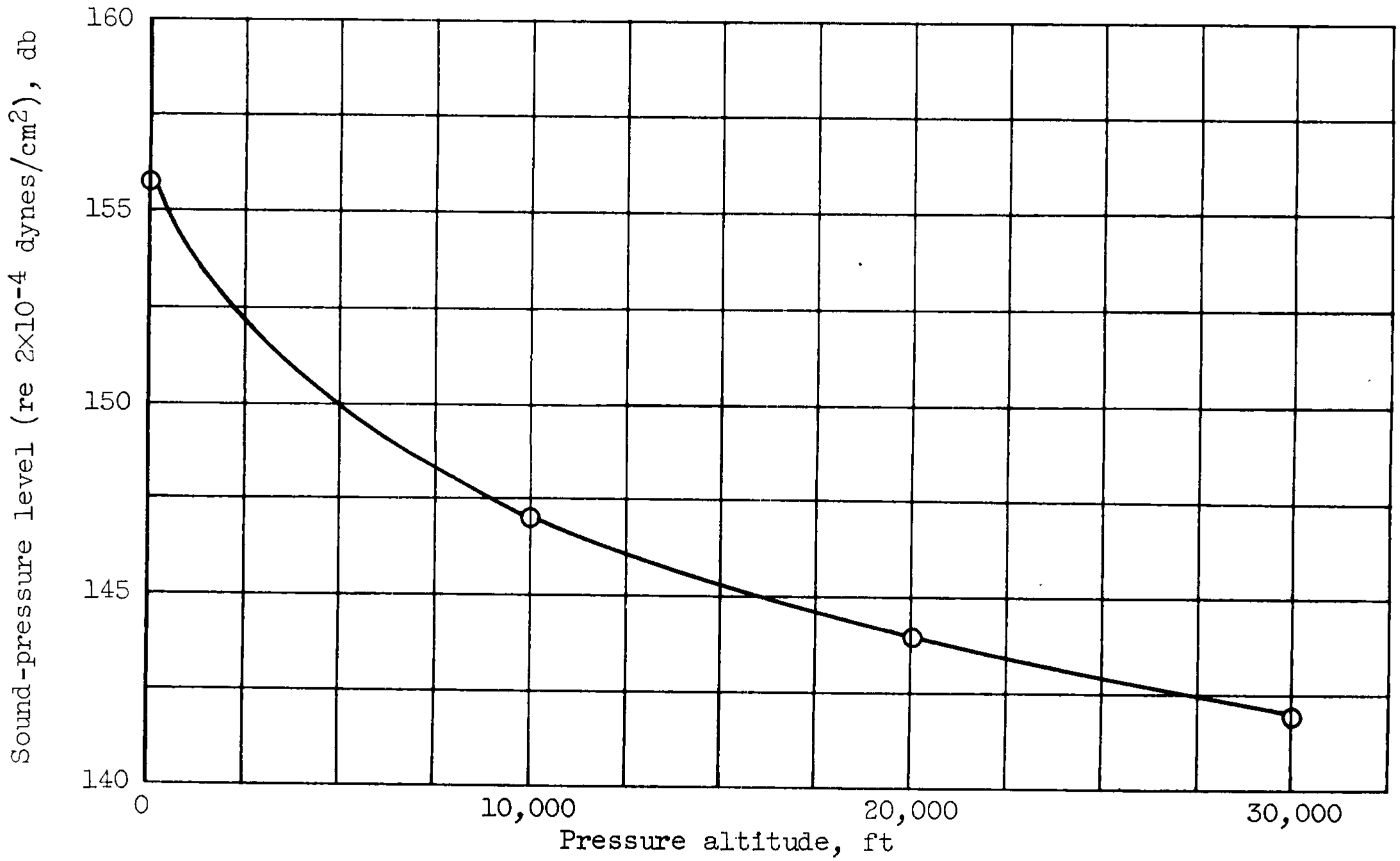
(c) Data as obtained from automatic recorder. Microphone positioned at 3 nozzle diameters.

Figure 6. - Concluded. Sound-pressure level as a function of Mach number.



(a) 2 Diameters.

Figure 7. - Sound-pressure level as a function of altitude.



(b) 3 Diameters.

Figure 7. - Concluded. Sound-pressure level as a function of altitude.

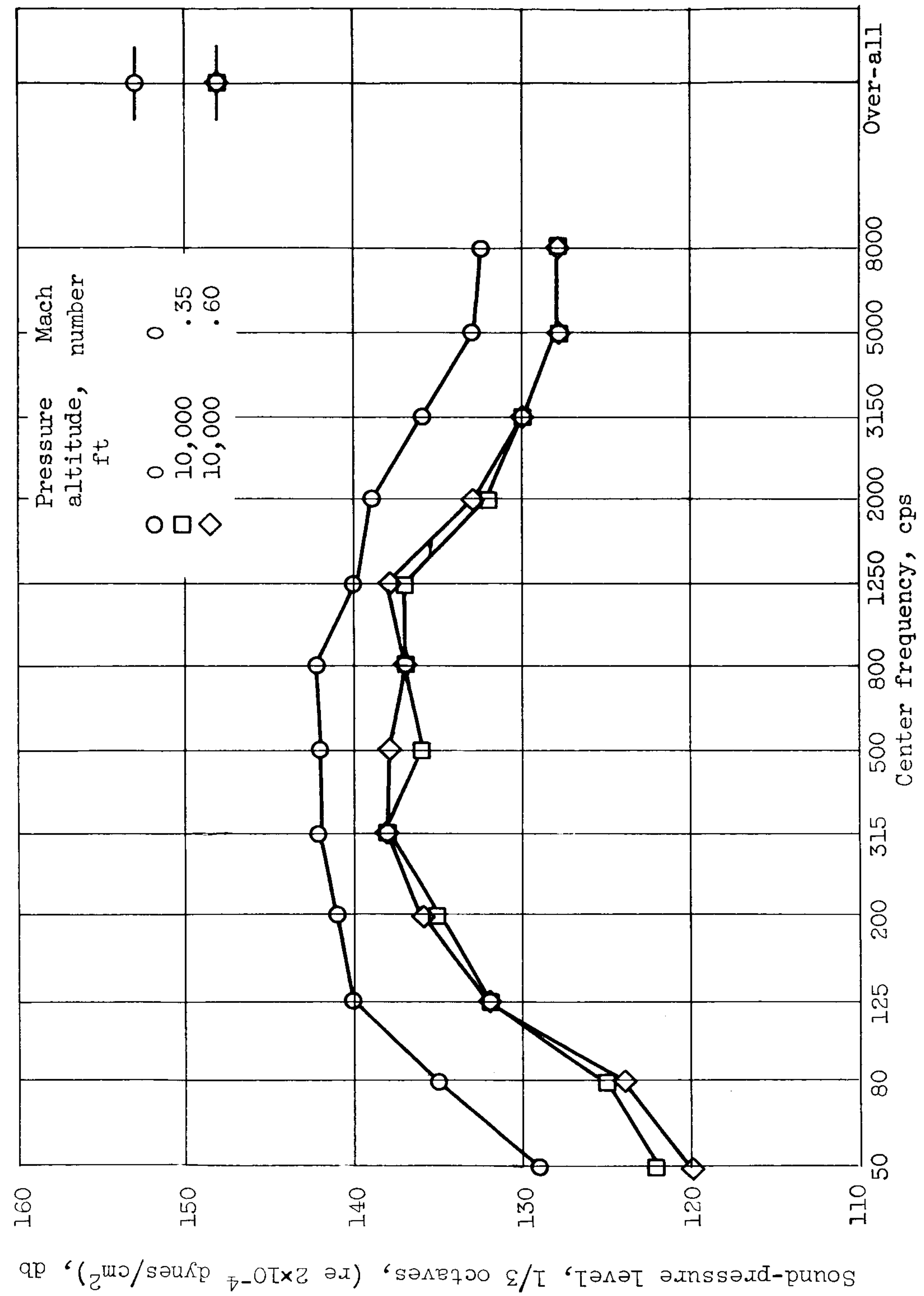


Figure 8. - Sound-level spectra.